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ON PHILADELPHITE (Sp. Nov.).

BY HENRY CARVILL LEWIS.

The mineral to which the above title has been applied was found by the writer four years ago, in what was then a quarry of hornblendic gneiss, close to the boundary of the Twenty-second Ward, Philadelphia. The locality is on Germantown Avenue, at the bridge crossing of the Germantown and Norristown Railroad, near Wayne Station. The quarry is now walled up, and is used as a coal and lime yard.

Geologically, the locality is just at the base of the terrace of metamorphic rocks which bounds the drift formations underlying the greater part of the city. Quaternary clays, boulders of the Champlain period, and tertiary gravels appear within a hundred feet of the quarry, and the waters of those different epochs have successively eroded the hill rising above it. This hill, here called Negley's or Logan's Hill, about 225 feet in height, is part of the same hill or " Upland Terrace," which, trending nearly northeast and southwest, has been traced continuously from here into Maryland, on the one side, and across New Jersey on the other, and which, though composed of quite different rocks in different places, forms throughout, the boundary of the post-jurassic formations.[1]

The rock at this place is a hard black hornblendic gneiss, subject to decomposition in its upper portions. It is well exposed in the cut on Wayne Street, where numerous minerals occur, and it is the same which is quarried at Frankford and at McKinney's quarry, both noted mineral localities. In its altered state it crumbles easily, and when heated exfoliates. In this condition, after being crushed in a mill between heavy iron rollers, it is sometimes used as a building sand.

The mineral here described as *Philadelphite* belongs to the vermiculite group of hydrous silicates. It occurs both disseminated in scales throughout the gangue-rock, and also in seams, an inch or more in thickness and many feet long. Associated with it in the same quarry are crystals of sphene, epidote and hornblende, and specks of chalcopyrite. It has been found in small quantities also at Wayne Street, at McKinney's quarry, and in Germantown.

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[1] *V.* Proc. Min. and Geolog. Section Acad. Nat. Sci., Phila., Nov., 1878.

Since most of the vermiculites occur in serpentinous or chloritic formations, it is to be noted that no such rocks occur here or in the vicinity. The mineral is probably derived originally from hornblende.

Physical Characters.—Hardness, 1.3; Specific gravity, 2.80 (taken in alcohol and referred to water). Lustre pearly. Color, by reflected light, bronze; by transmitted light, brownish red, and in very thin laminæ, brownish yellow. Opaque, except in thin pieces. Streak brownish yellow. Laminæ unelastic, readily flexible, tough, not brittle. Feel greasy.

Crystallographic Characters.—Monoclinic. Cleavage; basal, eminent; also, occasionally, a cleavage parallel to the diagonals. Striations crossing at about 90°, causing the mineral to break into nearly rectangular fragments, are sometimes observed, and these are parallel to the plane of the optic axes and to the diagonals of the rhomb. No triangular striations as in Jefferisite. Plates often contorted and wrinkled. Twin crystals frequent, observable by polarized light. Optically biaxial. Double refraction strong, negative. Optic-axial angle, 31°20′–39°30′; generally 37°±. Crystals sometimes nearly 2 inches wide and ½ inch high. The hyperbolas are well defined in the polariscope, and the angle of their divergence is more constant than in some of the other vermiculites. Twinning produces variations in the angle.[1]

Pyrognostic Characters.—In the closed tube it gives off water and exfoliates with great force, in a direction perpendicular to its base, to ten times its original volume. Upon exfoliation it becomes of a bright copper color and takes a metallic lustre. It also becomes brittle and more opaque. The exfoliated mineral has a far more distinct and frequent secondary vertical cleavage than it has before exfoliation, and the basal cleavage is also easier. It shows strong double refraction in the polariscope, and has an optical divergence of about the same amount as that of the unignited mineral (30° to 37°). The hyperbolas are extremely ill-defined, and no exact measurements could be taken. It is yellow by transmitted light. It forms a fine object under the microscope by reflected light. The fine copper color gained on exfoliation is characteristic, distinguishing it from the other vermiculites. The color is obtained whether it is heated suddenly in the flame, or slowly in an air-bath to exfoliation. Upon long-continued ignition in a platinum crucible, heated without access of air, it becomes a steel-gray color, its iron having been reduced. Before the blowpipe it gives the violet flame of potash and fuses to a black magnetic globule, which does not intumesce when further heated.

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[1] *V.* Prof. Cooke's Paper on the Vermiculites, Proc. Amer. Acad., Boston, 1874, 35.

With the fluxes it reacts for silica and iron. It is readily dissolved by hot sulphuric acid, the pure white silica being left in the original shape of the mica. It is dissolved in hydrochloric acid upon long digestion.

Chemical Composition.—In the investigation of the chemical composition of Philadelphite the writer has had the valuable advice of his friend, Prof. F. A. Genth, of the University of Pennsylvania. The method used in the estimation of vanadium is entirely due to him. The writer is also indebted to his friend, Mr. Reuben Haines, of Germantown, for two analyses, and for some interesting experiments.

Of the four analyses given below, Numbers I and II are by Mr. Haines; Nos. III and IV by the writer. Nos. I and II were made upon the pulverized mineral, previously dried in an air-bath at 100° C.; the hygroscopic water, amounting to over 3 p. c., not being included in the determinations. "In both the analyses the sample was dissolved in concentrated HCl, and the SiO_2 purified by digestion with HCl. The Fe and Al were precipitated together by NH_4HO and the Fe titrated by permanganate. The ferrous oxide was found by dissolving the weighed mineral in sulphuric acid in a closed flask from which the air was expelled by boiling with sodic carbonate, and titrating as before. The magnesia was weighed as pyrophosphate and the alkalies were separated by Smith's method of fusion, and were determined by platinic chloride, controlling the result by ignition of the platinic salt in hydrogen and weighing as metallic platinum. The combined H O is an average of the results of experiments Nos. IV and VI (given below) taken at a red heat on bottom of crucible."

Analyses Nos. III and IV were made upon the ignited mineral, this being considered its most constant state. The atomic water was determined separately, and the analysis of the anhydrous mineral reduced when the percentage of water was added. The ignited mineral being with difficulty soluble in acid, it was decomposed by fusion with sodic carbonate for analysis. After repeated evaporation of the silica with HCl, it was found still to contain titanic acid, which was extracted by evaporation with concentrated H_2SO_4 and precipitated by dilution and boiling. Additional titanic acid was separated upon boiling the filtrate from SiO_2, after reduction with H_2S. In one analysis titanic acid was separated from SiO_2 by volatilizing the latter with HF, dissolving the residue in H_2SO_4, diluting and boiling. Ferrous oxide was determined in the air-dried mineral as in analyses I and II. Iron and alumina were estimated by precipitation by boiling with sodic acetate in a neutral solution, dissolving in HCl, reprecipitating with NH_4HO, igniting and weighing together. In the filtrate MnO was precipitated by bromine and ignited.

The following method was employed for the detection of vanadium. 80 grammes of impure mineral were mixed with 90 grammes of sodic carbonate and 100 grammes of sulphur, and the whole heated slowly in a Hessian crucible covered by charcoal until partially fused. It was then digested in warm water, filtered, and to the filtrate dilute HCl was added, precipitating a copious heavy flocculent brown mass of the sulphides of vanadium, copper, cobalt and nickel. The precipitate was washed, ignited and evaporated with nitric acid, when it gave a red residue. This was fused with a mixture of sodic carbonate and sodic nitrate, and extracted with water in order to separate the oxides of copper, cobalt and nickel. Solid ammonic chloride was now added to the aqueous solution, when vanadate of ammonia was precipitated. Upon ignition it was changed to vanadic oxide, and was found to be pure, giving all the characteristic reactions.

For the estimation of vanadium the following method was employed. 4½ grammes of the pulverized ignited mica were fused with a mixture of 3 parts $NaCO_3$ and 1 part $NaNO_3$, the mass extracted with H_2O, filtered, and the filtrate digested with H_2S. Traces of CuS and FeS were filtered off, and the silica eliminated by evaporation to dryness and addition of dilute H_2SO_4. H_2S was again added, giving a blue solution. After driving off the H_2S by heat, the vanadic acid present was estimated volumetrically by the addition of a measured portion of a standard solution of permanganate of potash.

Magnesia was determined as pyrophosphate, and the alkalies by means of Smith's method. Phosphoric acid was precipitated as phosphomolybdate of ammonia, and weighed as pyrophosphate of magnesia.

On account of the remarkable hygroscopic powers of Philadelphite, great difficulty was experienced in the estimation of the combined water. Nearly one-half of the water in the air-dried mineral is hygroscopic, and may be driven off either by long exposure over sulphuric acid in a desiccator, or by drying in an air-bath at 100° C. The percentage of water given in the analyses represents approximately the amount of water in the mineral after such desiccation.

Spec grav. (taken in alcohol of 95 p. c.) 2.78–2.96.

	I.	II.	Mean.	Quantivalent ratio.		
SiO_2	39.06	38.52	38.79	2.587	2.587	5.45
Al_2O_3	14.75	14.82	14.78	.861	1.622	3.42
Fe_2O_3	20.59	20.01	20.30	.761		
Fe_2O	2.04	2.04	2.04	.056	.831	1.75
MnO	trace	trace	....	....		
MgO	11.49	11.32	11.40	.570		
CaO	.99	1.08	1.03	.037		
Na_2O	.90	.64	.77	.025		
Li_2O	trace	trace	....	....		
K_2O	6.89	6.61	6.75	.143		
F	trace	trace	....	....		
H_2O	4.27	4.27	4.27	.474	.474	1.—
	100.98	99.31	100.13			

Hygroscopic water in I, 3 12; in II, 3.43.

Spec. grav. (taken in alcohol of 84 p. c on the air-dried mineral) 2.80.

	III.	IV.	Mean.	Quantivalent ratio.			
SiO_2	35.94	35.52	35.73	2.38	2.43	5.05	5
TiO_2	1.30	.77	1.03	.05			
Al_2O_3	15.23	16.32	15.77	.91	1.65	3.43	3
Fe_2O_3	19.48	19.43	19.46	.73			
V_2O_3	.37	.36	.37	.01			
FeO	2.09	2.28	2.18	.06	.87	1.80	2
MnO	.46	.55	.50	.01			
NiO CoO	trace	.06	.06	..			
CuO	trace	.08	.08	..			
MgO	11.41	11.72	11.56	.58			
CaO	1.38	1.54	1.46	.05			
Na_2O	1.42	.38	.90	.03			
Li_2O	trace	trace	..	..			
K_2O	6.52	7.11	6.81	.14			
PO_5	trace	.11	.11	..			
Cl	trace	trace	..	..			
H_2SO_4	trace	trace	..	..			
H_2O	4.34	4.34	4.34	.48	.48	1.—	1
	99.94	100.63	100.45				

Hygroscopic water in III and IV, 3.24.

From both these pair of analyses we have the ratio

$\mathrm{R} : \bar{\mathrm{R}} : \mathrm{Si} : \mathrm{H} = 2 : 3 : 5 : 1$ and $\dot{\mathrm{R}}\,\dddot{\bar{\mathrm{R}}} : \ddot{\mathrm{Si}} : \dot{\bar{\mathrm{H}}} = 1 : 1 : \frac{1}{5}$. The ratio of bases to silica is 1 : 1, and for sesquioxides to protoxides, $\overset{\mathrm{vi}}{\bar{\mathrm{R}}} : \overset{\mathrm{ii}}{\mathrm{R}} = 2 : 1$.

Philadelphite dried at 100°C. appears to be a unisilicate, the water not being basic.

The formula may perhaps be written

$$\bar{\mathrm{Si}} \parallel \mathrm{O}_4 \parallel [\tfrac{2}{5}(\mathrm{K}_2, \bar{\mathrm{Mg}}) + \tfrac{3}{5}\beta(\bar{\mathrm{Al}}, \bar{\mathrm{Fe}})]_2 + \tfrac{2}{5}\,\mathrm{aq}$$

The general symbol would be,

$$\overset{\mathrm{ii}}{\mathrm{R}}_4, \overset{\mathrm{vi}}{\bar{\mathrm{R}}}_2, \mathrm{O}_{20}.\ \mathrm{Si}_5.\ 2\ \mathrm{H_2O}.$$

The water will be regarded as water of crystallization. Prof. Cooke has shown the close chemical relation between the anhydrous vermiculites and biotite. A like result is brought out by the following analysis of ignited Philadelphite. The analysis is a mean of the two analyses of the anhydrous mineral which formed analyses Nos. III and IV of the mineral dried at 100° C.

V.	$\frac{2}{2}$			Quant. ratio.	
$\mathrm{SiO_2}$	37.35	2.49	2.54	2.82	3
$\mathrm{TiO_2}$	1.08	.05			
$\mathrm{Al_2O_3}$	16.49	.96	1.73	1.92	2
$\mathrm{Fe_2O_3}$	20.33	.76			
$\mathrm{V_2O_3}$	.38	.01			
FeO	2.28	.06	.90	1.—	1
MnO	.52	.01			
MgO	12.09	.60			
CaO	1.53	.05			
$\mathrm{Na_2O}$	.94	.03			
$\mathrm{K_2O}$	7.13	.15			
	100.12				

Here $\overset{\mathrm{ii}}{\mathrm{R}} : \overset{\mathrm{vi}}{\bar{\mathrm{R}}} : \mathrm{Si} = 1 : 2 : 3$, the ratio of a typical biotite. Analgous as the anhydrous mineral is to biotite in its formula, it has been shown that physically and optically the two minerals are quite dissimilar, and it is not proven that they have any necessary connection. It is by no means a hydrous biotite in the sense that margarodite is a hydrous muscovite, in which case the characters, optical and physical, are identical. Such hydrous biotites occur in several places in the vicinity of Philadelphia, in a partially altered micaceous gneiss, in which the muscovite has become margarodite, and the orthoclase become white and crumbling. Such mica exfoliates slightly when heated, is uniaxial, fusible with difficulty, and might be called *Hydrobiotite* for convenience. It frequently occurs enclosed in crystals of margarodite, or in muscovite passing into margarodite.

Hygroscopic Properties.—In the determination of water in its different states in Philadelphite, the principal difficulty was on account of the strong hygroscopic properties possessed by the mineral. After the water has been expelled by heat or desiccation, it is rapidly absorbed again from the air, if exposed. Upon the balance, the dried mineral gains so rapidly that it was found necessary while weighing to enclose it in corked tubes. It appears to absorb water with the avidity of chloride of calcium. Even when enclosed in watch-glasses clasped together and standing in the closed balance-case with dry $CaCl_2$, it gains decidedly in weight. The following experiments by Mr. Haines illustrate its hygroscopic properties :

	Grammes.
(1) Weight of undried mica,	.9935
Heated at 100° C. for 1½ hours,	.9616
Weight after standing in balance-case with $CaCl_2$ for 3 days,	.9915
Reheated for 3 hours at 100° C.,	.9580
Left on balance 20 minutes. Gain in weight,	.0070
Left on balance 2 hours. Total gain in weight,	.0085
(2) Weight of undried mica,	1.1280
Heated at 100° C. for 3 hours,	1.0965
Left in balance-case with $CaCl_2$ for 1 hour,	1.1175
Left in balance-case with $CaCl_2$ for 1½ hours,	1.1230
Left in balance-case with $CaCl_2$ for 2½ hours,	1.1250
Left in balance-case with $CaCl_2$ for 2 days,	1.1260
(3) Undried mica heated at 100° C. for 6½ hours. Loss,	2.49 p. c.
On standing in balance-case with $CaCl_2$ for 2½ days, regained nearly the whole of its original weight (all but 2 milligrammes). Again heated at 100° for 3 hours, loss of weight,	3.09 p. c.

These experiments, showing that nearly the total amount of hygroscopic water is regained even in the presence of such an active desiccator as chloride of calcium, indicate a remarkable hygroscopic force in the dried substance; a property not easy to explain. It will be noticed that this force is exercised much more powerfully immediately after desiccation than it is after a lapse of time. Experiment No. (2) shows that two-thirds of the water is absorbed during the first hour. It has been found that the amount of water in the powdered mineral varies with the hygrometric state of the atmosphere at the time of weighing. It is interesting to note that several of the zeolites, a class of hydrous silicates whose exfoliation by heat is very like that of the vermiculites, also have strong hygroscopic powers, losing and regaining part of their water with ease.[1]

Water of Crystallization.—The water in Philadelphite probably exists in three theoretical conditions, viz.:—Hygroscopic water, water of crystallization and water of constitution. The first is driven off by drying at 100° C. or by exposure to dry air over H_2SO_4; the second by gentle ignition, and is accompanied by exfoliation; the third by strong and prolonged ignition. The latter, which probably does not much exceed 1 per cent., and which the analyses have shown is not needed with the basic radicals to complete the unisilicate formula, will be regarded with the water of crystallization. The most satisfactory determinations of the water of crystallization have been made by subtracting the hygroscopic water from the total water.

The following experiments have been made upon the amount and condition of the water.

(1). The dry mica, which had been out of the quarry for more than a year, was cut into pieces about 5 mm. square, heated in a platinum crucible to a bright red heat for 25 minutes, cooled in a desiccator over H_2SO_4 for half an hour, and then quickly weighed. It lost 7.58 per cent., which will be regarded as the total amount of water.

(2). The finely powdered mica holds more water. Different experiments gave:—7.84 (ignited 10 minutes), 7.89, 7.90, 8.11 (ignited 25 minutes), 7.50 (powdered just previous to ignition). Strong ignition of the powdered mica probably volatilizes some of the alkalies in addition to the water.

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[1] Damour (Ann. d. Mines, IV, x, 208) shows by an experiment similar to those given above, that the water lost by heulandite exposed over H_2SO_4 is all regained in 1½ days.

(3) The finely powdered mica was divided into two portions, one of which was spread out on an open watch-glass, the other placed in a crucible. Both were weighed, put in a desiccator over sulphuric acid, and let stand unopened for two months. That in the crucible lost 2.76 per cent. of water. That on the watch-glass had lost 3.87 per cent. On standing 3 or 4 minutes upon the scale-pan it gained .53 per cent. of water from the air. Upon exposure over sulphuric acid in the desiccator 24 hours longer and then being quickly weighed, it was found to have lost 3.99 per cent. It was now placed in an air-bath and kept at a temperature of 100° C. for 4 hours. After cooling 15 minutes in the desiccator, it was found to have gained in weight about ½ per cent., indicating that the desiccation over sulphuric acid was more complete than that in the air-bath at 100° C. That in the crucible lost on ignition 5.97 per cent. of its weight.

(4). The powdered mica was placed in a watch-glass in a desiccator over sulphuric acid.

After 27 days it had lost 2.28 per cent.
" 40 " " " 2.36 "

During weighing, it was enclosed in clasped watch-glasses. It was now put in a crucible and ignited.

The dried mineral lost on 1st ignition, 5.18 per cent.
" " " 2d " 5.36 "
" " " 3d " 5.47 "

(5). The following direct determinations of water of crystallization were made from the mica, dried in a glass tube, corked while weighing, and then ignited in a crucible.

	Desiccation.	Time of Desiccation.	Ignition	Loss of water in dried mineral.
(a)	100° C. in air-bath.	24 hours.	15 min.	5.38 p. c.
(b)	" "	3 days.	20 min.	5. "
(c)	over H_2SO_4	2 weeks.	3 times.	5.60 "
			Mean,	5.32 "

This determination is thought to be too high, including some hygroscopic water, since the mica in a tube cannot be perfectly desiccated.

A mean of the three determinations of hygroscopic water absorbed over sulphuric acid gives 3.24 per cent., which deducted from the total water, 7.58 per cent., gives for water of crystallization, 4.34 per cent. As will be seen below, a similar amount is deduced from Mr. Haines' experiments.

The following experiments by Mr. Haines have been kindly placed at the disposal of the writer. They may be relied upon as having been performed with great care.

I. The powdered mica is placed in a desiccator over concentrated sulphuric acid.

(a)	Dried 15 days.	Loss, 2.69 per cent.
(b)	" 10 "	" 2.89 "

II. The undried mica is heated in an air-bath at 100° C.

(a)	Heated 3 hours.	Loss, 3.14 per cent.
(b)		" 3.33 "
(c)		" 3.42 "
(d)	" 5½ "	" 3.69 "

	Weights.	Per cent. of loss.
III. Weight before heating.	1.0880	
Heated at 100°, 1½ hours.	1.0613	2.46
" " 4½ "	1.0598	2.59
Over H_2SO_4 and heated 5 hours at 100°.	1.0558	2.96
Heated 2 hours at 100° and cooled over H_2SO_4.	1.0613	2.46

	Weight.	Total loss.	Loss from 100° C.	Increment of loss.	p.c. of total loss.	p.c. of loss fr. 100°C
IV. Weight before heating.	.9035					
Heated at 100° C. for 1 hr.	.8743	.0292			3.23	
" 100° " 2 "	.8730	.0305			3 37	
" 105° " 2½ "	.8715	.0320	.0015	.0015	3.54	0.15
" 119° " 1 "	.8705	.0330	.0025	.0010	3.65	0.28
" full red heat 5 min.	.8350	.0685	.0380	.0355	7.58	4.34
" over blast lamp 1st time.	.8270	.0765	.0460	.0080	8.46	5.27
" over blast lamp 2d time.	.8280	.0755	.0450		8.35	5.15

	Weight.	Total loss.	Loss from 100° C.	Increment of loss.	p.c. of total loss.	p.c. of loss fr. 100°C
V. Weight of undried mica	.8052					
" at 100° C.	.7827	.0225			2.79	
" at 125° C. cooled for 3 minutes.	.7757	.0295	.0070	.0070	3.66	0.89
" at 150° cooled for 3 minutes.	.7682	.0370	.0145	.0075	4.59	1.85
" at 170°–175° cooled for 4 min.	.7682	.0370	.0145		4.59	1.85
" 190° cooled for 3 minutes.	.7647	.0405	.0180	.0035	5.03	2.30
VI. Weight of undried mica.	.9855					
" at 100°C, heated several hours.	.9615	.0240			2.43	
Below faint red heat.	.9445	.0410	.0170	.0170	4.16	1.77
Heated to pale red at bottom of crucible.	.9320	.0535	.0295	.0125	5.32	3.07
Heated to bright red at bottom of crucible.	.9210	.0645	.0405	.0110	6.54	4.21
Heated to full red on whole crucible.	.9148	.0707	.0467	.0062	7.17	4.85

VII. Total water.

(a) Loss of weight at red heat, 7.30 per cent.
(b) " " on ignition, 7.50 "
(c) " " " 3 times, 7.86 "

From the above experiments of Mr. Haines in connection with Nos. (1), (2) and (3) under "hygroscopic properties," we may deduce the following percentages:

For total water, we have (IV), 7.58 p. c.; (VI), 7.17; (VII, a, b, c), 7.30, 7.50, 7.86.

Mean total water, 7.48 per cent.

For hygroscopic water, driven off at 100°, we have

Analysis I.	Analysis II.	Exp. (1) Heated 1½ hrs.	Exp. (1) Reheated 3 hrs.	Exp. (2) 3 hrs.	Exp. (3) 3 hrs.
3.12	3.43	3.21	3.57	2.79	3.09

Exp. II a 3 hrs.	Exp. II b	Exp. II c	Exp. II d 5½ hrs.	Exp. III. 5 hrs.	Exp. IV. 2 hrs.	Exp. V.	Exp. VI. several hrs.
3.14	3.33	3.42	3.69.	2.96	3.37	2.79	2.43

A mean of these 14 determinations gives for hygroscopic water 3.17 per cent.

Subtracting this from the mean total water, 7.48 per cent., we have for water of crystallization 4.31 per cent., an amount closely agreeing with that deduced from the writer's experiments. The desiccation over sulphuric acid in Exp. I is for too short a time to completely extract the hygroscopic water.

The exact state of the water cannot yet be regarded as certainly established. There is no reason why a fixed temperature of 100° C. should divide the hygroscopic water from the water of crystallization. The above experiments show that the loss of water as the temperature is raised above that point is a very gradual one. It is difficult to see in what manner the water driven off at 190° in experiment V, differs from that driven off at 100°. It will be seen hereafter that much of the water can be driven off without exfoliation. Again, there is no sufficient reason why some of the water absorbed by sulphuric acid in the desiccator may not be water of crystallization. It has been long known that sulphate of copper either at 100° C. or in a desiccator over sulphuric acid loses much of its water of crystallization. M. Damour has shown that chabazite loses nearly half of its water in a desiccator. It seems probable that Philadelphite, with other vermiculites, holds its water in a similar manner. From the experiments here detailed it would seem that we may define water of constitution to be the more closely combined, and hygroscopic water the less closely combined water of crystallization; and the distinction between the three states of water then becomes a theoretical rather than a practical one.

Temperature of Exfoliation.—The temperature at which exfoliation occurs is from 150° to 160° C. It has been found that the exfoliation temperature is proportional directly to the original volume of the substance, and inversely to the rapidity of the application of heat. The larger the piece experimented upon, the higher the temperature necessary to make it exfoliate, and the more rapidly the heat can be applied, the sooner will it exfoliate; as the following experiments will show.

(*a*) Very small fragments heated on a watch-glass in an air-bath began to exfoliate at 150° C.

(*b*) A large piece heated similarly did not exfoliate at 210° C.

(*c*) A piece was immersed in melted paraffine. At 100° C.

bubbles went off slowly, but there was no exfoliation. The temperature being raised, it made the first movement at 160°, exfoliated vigorously at 175°, and at 180° rose from its support to the surface of the paraffine.

(*d*) Another piece similarly immersed gave bubbles briskly at 130°, and began to exfoliate at 160°.

(*e*) Pieces thrown into melted paraffine whose temperature had previously been raised to 160° C., immediately exfoliated and rose to the surface.

(*f*) A large piece did not exfoliate even after the temperature had been gradually raised to 225° C.

(*g*) Immersed in melted sulphur, it immediately exfoliated and strongly effervesced.

(*h*) Immersed in concentrated sulphuric acid which had been heated to 160° C., it immediately exfoliated and became pure white, being completely and immediately decomposed. Immersed similarly at a temperature of 150° C. it exfoliated, but did not become immediately white. At a lower temperature no exfoliation occurred. A similar piece being similarly immersed and the temperature raised, began to exfoliate at 130° C., and continued exfoliating as the temperature rose, though being meanwhile decomposed. This sudden change of form and color upon immersion in hot sulphuric acid recalls a somewhat similar change in the efflorescence of protosulphate of iron when immersed in the same acid.

It is seen from these experiments that no absolute determination of the exfoliation temperature is possible. By a very slow heat a large proportion of the water (about 5 per cent.) can be driven off and the mica raised to a high heat without any exfoliation of consequence. The following experiment illustrates this fact.

(*k*) A piece of Philadelphite was cut into two equal portions. One piece, heated suddenly on platinum foil to a red heat, exfoliated to ten times its original volume. The other piece was slowly heated in an air-bath. At 285° C. it had exfoliated but very slightly. It was then taken out and heated on platinum foil to a red heat, when it exfoliated very little more, becoming only one-fourth the length of the first piece.

A similar experiment has been made upon heulandite and stilbite from near Philadelphia. Both of these zeolites, as is well known, exfoliate largely when held in the flame. It has been found that if they are heated very slowly on platinum foil, they can be raised to a white heat without exfoliation, and when afterwards held in the flame, exfoliate but slightly. Apparently the water in Philadelphite is combined precisely as in the zeolites

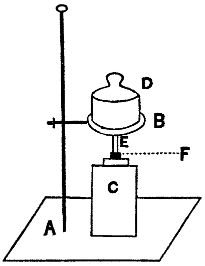
It appears that it is as difficult to make a distinction between water of crystallization and water of constitution as it is to make one between the former and hygroscopic water.

Amount of Exfoliation.—The amount of exfoliation is quite constant at ten times the original volume.

Original thickness. Inches.	Thickness after exfoliation. Inches.		Ratio.
.015	.13	mean	1 : 10
.015	.17		
.02	.2		1 : 10
.03	.25	mean	1 : 10.4
.04	.47		
.06	.68		

These experiments were made by heating the mica on platinum foil over the flame of a Bunsen burner. The heat must be sudden in order to have a large exfoliation (*v.* Exp't. *k*). Exfoliation takes place in one direction only, viz., at right angles to the cleavage. No lateral expansion whatever occurs. When the flame is applied to one side of the mica, that side exfoliates the most, and causes the exfoliating mineral to curve in the opposite direction.

Force of Exfoliation.—It has been found that the force exercised during the exfoliation of Philadelphite is enormous. In one experiment a fragment of it while exfoliating lifted more than 50,000 times its own weight. The force of exfoliation is governed by a law which is the inverse of that controlling the exfoliation temperature. It may be stated thus: The force of exfoliation increases directly with the rapidity of the expulsion of water, and inversely with the volume of the substance. The latter part ot the law follows as a necessary consequence of the first part, since the smaller the fragment, the more rapidly and completely can it be heated. Various experiments were made, and though performed in an extremely rough manner, will give an idea of this force. To find what amount a given weight of the mica could lift when exfoliating, iron pound-weights were placed upon the ring of a retort stand and connected with the fragment of mica placed on a support immediately below them. A pencil of chalk or gas carbon resting loosely in a perpendicular position between the mica and the centre of the weights connected them so that any expansion of the mica would lift the weights from off the ring on which they rested. The blowpipe flame was now directed from one side upon the mica.



a, retort stand.
b, ring.
c, support.
d, weight.
e, pencil of chalk.
f, fragment of mica.

In the following table of experiments, the first column represents the weight of the fragment of mica, and the second column, the iron weight which was lifted by the exfoliating mica.

Philadelphite.		Weight.		
15 grains	lifted	10 lbs.	avoirdupois.	
6 “	“	10 lbs.	“	
5½ “	“	10 lbs.	“	
2½ “	“	10 lbs.	“	
2 “	“	5 lbs.	“	
1½ “	“	2 lbs.	“	
1 “	“	3 lbs.	“	
⅔ “	“	2 lbs.	“	
½ “	“	3 lbs.	“	readily.
½ “	“	4 lbs.	“	“

In the last experiment the four-pound weight was lifted up and thrown off the ring supporting it; the weight lifted being 56,000 times the weight of the mica.

A remarkable motive power is here developed. That it is owing solely to the escape of the combined water is shown by the fact that if the weights are so arranged that the mica can only slightly expand, and, after heating, are removed, the mica will expand no more, or very slightly more, upon further application of heat, the water having been in great part expelled. If the mica is confined under a weight so heavy that it is impossible for it to exfoliate, and is suddenly heated by the flame, it occasionally explodes with a loud report, throwing off fragments laterally into the air.

It may be stated that the exfoliated mineral when powdered, forms a handsome and permanent bronze powder not liable to tarnish, and useful in the arts.